Extending the Palette

An analysis of the heterogeneity of techniques for communicating space

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This study offers an analysis of the increasing range of communication methods required by the emerging profession of the architectural technologist. It reviews the process of introducing methods of communication into the academic curriculum of undergraduate architectural technology students who have a need to select appropriate techniques in order to communicate to various stakeholders, design teams and clients. The paper reviews the integration of three-dimensional computer modelling technologies for the analysis and communication of proposed designs and considers the knowledge and skills which will be required to enable effective representation of increasingly complex buildings.

Keywords: *Architectural Technology; Undergraduate Curriculum; Communication Methods; Virtual Reality.*

Introduction

In the UK the profession of Architectural Technology (AT) is emerging because of a need to 'bridge the gap' between design and construction. An increasing number of accredited degree courses in Architectural Technology are preparing graduates to take leading roles in an industry striving for improved integration amongst built environment professionals. Architectural technologists, surrounded by such professionals, have a specific need for effective communication in order to resolve design and technical issues and ensure optimum building performance and efficiency. An ever-increasing range of techniques for the representation of building components, buildings and landscapes is available for students who enter higher education increasingly computer literate, and with expectations that they will be introduced to appropriate knowledge and skills required by their profession. AT graduates need to 'be able to analyse, synthesise and evaluate design factors in order to produce design solutions, which will satisfy performance, production and procurement criteria' [1].

Education of the architectural technologist

The undergraduate degree programme in Architectural Technology at Northumbria University, School of the Built Environment, was developed in 1998 in response to this need of the UK construction industry. The course delivery and modular design responded to influences from government policy, employers' expectations and the pedagogical requirements of

1 www.ciat.org.uk: Jan 2006

higher education. The program was viewed as having a close affinity with both construction and architecture programmes and students are taught jointly in lectures, seminars and projects with at least two other programmes, alongside specialist subjects for their discipline. The requirement of the architectural technologist to be able to convey the technology of buildings to a variety of interested parties has placed emphasis on students' ability to communicate appropriately using both traditional and computer-based representations. Keeping up-to-date with accelerating technologies for visualization is a challenge for academics who have to balance this requirement with a need to ensure that the technology is appropriately applied, and introduced alongside other key subjects in the curriculum. The concern discussed by Maver (1999) that traditional teaching methods tend to separate subjects has resulted in much effort by academics to work in an integrated way, despite subjects being introduced in a modular, rather than studio-based, framework. Another challenge is to clarify the roles and responsibilities of the architectural technologist and differentiate them from those of the architectural technician - an area that has caused a degree of confusion for some time (Emmitt, 2002). Architectural technologists have a requirement to be able to communicate effectively for a variety of needs. Interested parties require different kinds of information, at different times, and students need to learn to select appropriately from an ever-increasing palette of representational techniques.

Methods of communicating space

Historical Perspective

There have been many major developments throughout history that have influenced the way buildings have been represented. An analysis of drawing aids (Hambley, 1985) reminds us of the introduction of ruling pens, compasses and sectors in the 16th century, followed by dividers, set squares, pencil leads in the 17th century. Drawing boards were introduced in 1734 and protractors were evident around this period. The 19th century, a great period of innovation and invention, witnessed the birth of photography, tracing paper, scale rules, technical drawing pens and architectural blue-prints. 1937 witnessed the introduction of photocopying. Any deeper analysis offering a historical perspective on architectural representation is valuable in confirming the revolutionary developments of today, yet offering a reminder of a rich heritage and respect for the traditional (Giddings & Horne, 2002).

2D CAD

The advent of computer aided drafting offered a dramatic change to the methods and representations of the past. Designs were translated into 2D drawings on computer screens, dependent on computer software and skilled operators. The discipline of the architectural technician emerged formally in 1958 and was extended, as technologies developed, to include that of CAD draftsmanship. Working drawings produced by electronic means, communicating design to constructors, became well established. Several associations were formed in the early 1980s to facilitate communication and critical thinking regarding computing in architecture. Yet whilst there have been many advances over recent years, CAD for many still means electronic drafting – i.e. a new tool for an existing skill, with 80% of drawings in the UK construction industry still done in 2D (CIRIA, 2005).

3D Modelling

The spectacular evolution of computer animation (Thalmann & Thalmann, 1992) has offered great advances and extensions to the traditional forms of representation. Also a rapidly advancing computer games industry has contributed to decreasing prices of software and hardware, and has offered lessons in the creation of artificial worlds (Richens & Tindet, 1999). Since the mid-1980s the software industry has responded to the needs of architecture by producing specific tools to aid the creation of three-dimensional models. Effective application of 3D modelling today has extended the role of CAD from design representation to design exploration, and it is this functionality that is of importance to the architectural technologist and their need to work with others. Recent advances in commercially available object oriented modelling software resulted in its adoption and integration into the academic curriculum for AT students at Northumbria, focusing initially on its application as a visualization tool (Horne et al, 2005). Building information modelling, and a new generation of software designed with buildings as focus is heralding a new way of working and is generating much debate, concern and critical analysis. Exploration of its ability to interface with Virtual Reality (VR) technologies (Johansson & Roupé, 2005), may eventually enable factors of interactivity and immersiveness to be available earlier in the design process.

Virtual Reality

The history of VR can be traced back to the early 1950s, although most of the key developments occurred in the USA in the 1980s (Stone, 1994). Previously considered unaffordable and inaccessible, requiring specialist facilities, the possibilities for VR within architectural education were defined several years ago (Alvardo & Maver, 1999). Since that time research has continued into the use of Virtual Reality for design education (Achten, 2004; Bourdakis, 2002; Kalisperis, 2002; Petric, 2003; Schnabel, 2001) as well as VR for construction education (Haque, 2005; Shelbourn, 2001). More recently, research has focused specifically on the integration of commercially available VR technologies within a broader built environment curriculum (Horne & Hamza, 2006) and raised issues relating to effective integration and application.

Methodology

This paper presents data that was gathered by observation, useful during both the formative and summative phases of an evaluation (Frechtling & Sharp, 1997). The author's role was that of an academic with remit to introduce communication technologies into the curriculum of undergraduate students of architectural technology. For this research the author assumes the role of 'Participant as Observer' and draws on personal involvement to provide further insight. Participation observation is a qualitative research method where the objective is to get to the root of the issues and discover the delicate nuances of meaning and result (Saunders et al, 2000). In addition, a case study approach is adopted to describe the students' experience in integrating new technologies into their design projects. This will enable depiction of the process and end results and provide a means to convey knowledge and understanding gained. Student feedback is analyzed qualitatively to assess their evaluations on the integration of three-dimensional modelling technologies.

Observations

Observations have been gained, over three consecutive years, in relation to the process and end results of extending traditional forms of representation and integrating three-dimensional computer modelling technologies into the academic curriculum. Pedagogical expectations were related to a constructivist approach which aims towards a rounded graduate with more than just a simple acquisition of skills, but the ability to apply knowledge and a process of critical judgment (Spivey, 1997).

Introduction of building information modelling 2003 / 2004

The Architectural Technology students were taught Computer Aided Drafting in the first year of their course, which introduced them to 2D CAD techniques still predominately used in industry. The teaching approach adopted for first year students of CAD was that of a systematic, logical introduction to the computer software capabilities, related to built environment projects. Thereafter students were expected to use CAD appropriately throughout their degree programme, including a year in professional practice, and to maintain and develop their skills via independent learning.

It was decided to introduce building information modelling software (Autodesk Revit) in the students' second year as it would enable them to produce 3D models in a much faster time than would have been possible using traditional 3D CAD. They were introduced, via a series of structured lectures, to the concepts of object oriented modelling and the fundamental differences between building information modelling and CAD, enhancing their understanding of essential facts, concepts, principles and theories relevant to this subject. The lecture programme focussed on the visualisation capabilities of Revit, albeit the students became aware that this software could be used for many other purposes, including the production of working drawings and sections. Figure 1 illustrates the second year module grid and the way computer aided visualization and three dimensional modelling sits alongside other key subjects.

Staff introducing Revit worked closely with academic staff teaching modules on Building Envelope and Environmental Services as well as Professional Practice Project and coordinated teaching delivery, assignment hand in dates and assessments to enable the students to focus on the application of the software once the basic skills had been acquired. Figure 2 shows the end results of students' projects using Revit and demonstrated students' abilities to produce high quality visualizations of buildings which had been modeled to a high level of technical detail, both internally and externally.

Figure 1
BSc Architectural Technology year 2 module grid

Semester 1	Management Skills Sem. 2, 10pts	Building Technology Applications Year Long, 20pts	Building Envelope & Environmental Services Year Long, 20pts	Computer Aided Visualisation and 3D Modelling Year Long, 20pts	Professional Practice Project AT Year Long, 20pts	Construction and economics Sem. 2, 10pts
Semester 2	Design Principles & Procedures Sem. 1, 10pts					Site Surveying Sem. 1, 10pts

Figure 2
Rendered images from models of a five storey building modeled using Revit 5.1.

Introduction of Virtual Reality 2004 / 2005

During the following academic year the School implemented desk-top VR facilities and also a stereo passive semi-immersive virtual environment for the purpose of introducing VR into the academic curriculum of final year undergraduate students (Horne & Hamza, 2006). The search for low-cost, accessible approaches to VR has been ongoing (Kalisperis, 2002; Achten, 2004) and the increasing power of PCs and graphics cards is making the technology accessible to those with computers typically found in many offices. The Virtual Environment in the School was based around a rear-projected display screen driven by a Dell PC with dual P4 Xeon processors and NVIDIA Quadro FX 3400 graphics cards.

Once again, a standalone module was designed into the curriculum for final year students of architectural technology, but an integrated approach was adopted for its application once the basic skills of the software (3dsMax and VR4Max) had been acquired. Figure 3 illustrates the final year module grid and the way virtual reality sits alongside other key subjects.

Integration of VR with the final year Design Project enabled students to interact with their designs in a way that had not been possible previously. In addition, students learnt how to program interactive behaviors into their models which enabled the opening and closing of doors, exploration of material options for external and internal cladding, movement of elevators and vehicles. Such behaviors aided the perception of immersiveness when navigating around the models in stereoscopic in the Virtual Environment. Figure 4 shows the end results of students' projects using Revit, 3ds Max and VR4Max and demonstrated how non-VR specialists could produce fairly sophisticated VR models using commercially available software.

Figure 4
Rendered image from a model of a timber-framed house using 3dsMax 7 and VR4Max..

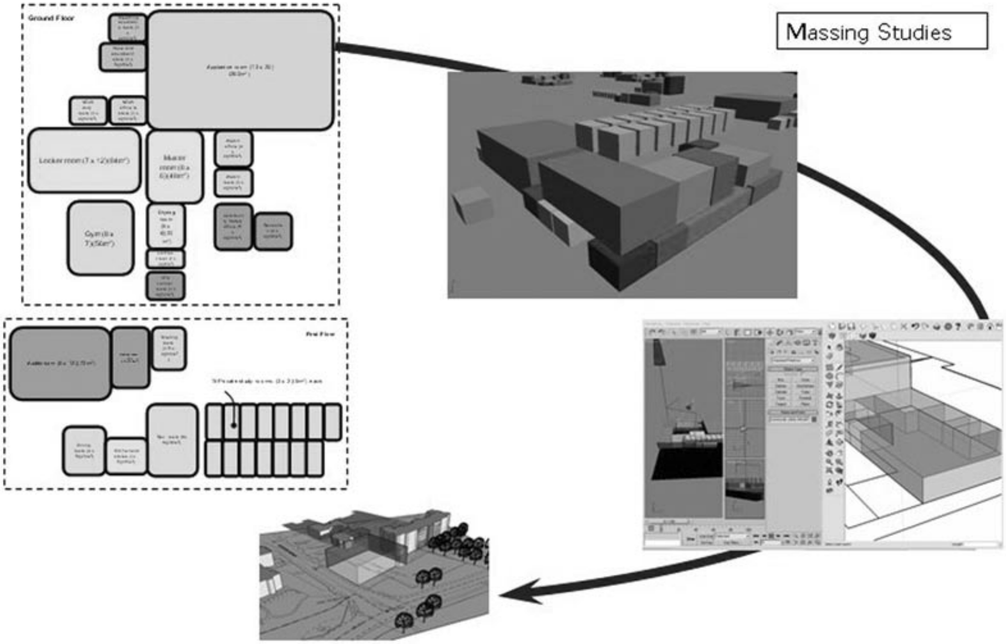
Application of Virtual Reality – 2005 / 2006

The third year of this study, 2005/2006, offers a case study of a student project which depicts the student's experience of selecting appropriate communication techniques from an extended palette. SketchUp was introduced for these students and made available for use, alongside other software, for their final year design project. The student selected 2D and 3D representations to communicate the design of a fire station. The design stage began with massing studies to consider the spatial requirements defined in the design brief. 2D bubble diagrams were used for this spatial analysis but also complemented by 3D volumetric models produced using 3ds Max. Having completed a suitable massing scheme and layout, a model of the scheme was then created using SketchUp software. 2D detailed scaled maps of the loca-

Semester 1	Production of Buildings	Managing the Design Process	Virtual Reality for the Built Environement	Design Project	Dissertation	Contracts & Procurement Sem. 1 10pts
Semester 2	Year Long, 20pts	Year Long, 20pts	Year Long, 20pts	Year Long, 20pts	Year Long, 30pts	

Figure 3
BSc Architectural Technology final year module grid

Figure 5
Massing Study showing process of selected 2D and 3D representation



tion were imported from DigiMap so that the various buildings and rooms making up the fire station could be realistically positioned on site. A simple day lighting design was carried out in SketchUp to refine the room layouts for maximum functional and thermal efficiencies.

After having established an optimal layout, the design process continued with an exploration of possible designs which were modeled in SketchUp. Texture mapping over the Digimap site data, as well as on neighbouring buildings, was integrated into the study at this stage. Varieties of solutions became apparent but were narrowed down to a number of factors relating to site limitations, building regulations, feasibility and buildability.

The model was mapped with photographic images taken during a site visit to a modern fire station. The final model was constantly transferred between programs to take advantage of the features of various applications. Autodesk Revit was used to model the detail of the building and simulate the shading conditions from neighbouring buildings. Data was transferred into IES for energy analysis simulation and building technologies and materials were explored using SketchUp to simulate the construction.

Having established a final layout and design, details were exported into AutoCAD and Revit to represent the detailed design. Exact dimensions were finalized and spaces were adjusted to suit their intended use, building regulations, furniture and manufacturers details. AutoCAD was used for extensive detailing of the building sections. After a completed design was established, the revised final model was built. The model from the early design stages was used and adapted to be consistent with the AutoCAD detailed drawings. CAD details, such as site layout and room plans, were exported into 3dsMax and an accurate, detailed model was made.

The completed model could communicate both internal and external spaces and could also support

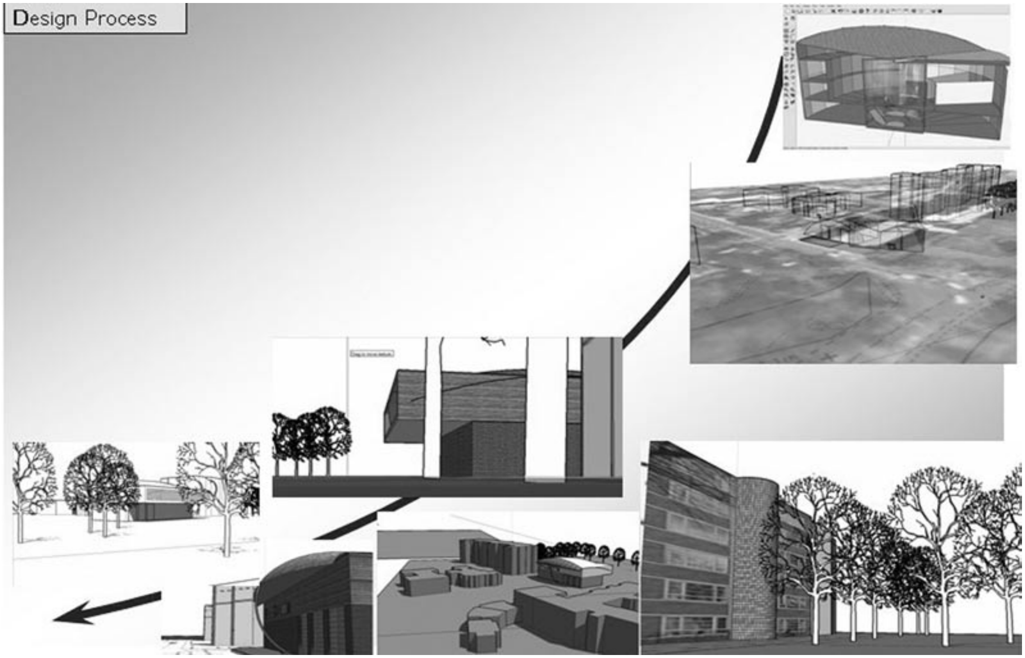


Figure 6
Design Process showing exploration of early scheme designs using SketchUp

interactive, immersive navigation when exported to VR4Max. Behaviours were programmed into the model to provide key press access to important view ports that might be of interest to a client, including visual representation of air flow and heat loss.

Observations

The study has offered evidence of the acceptance, by students of Architectural Technology, of new technologies to further their need for effective communication. Students are considering appropriate application of various technologies for various stages of

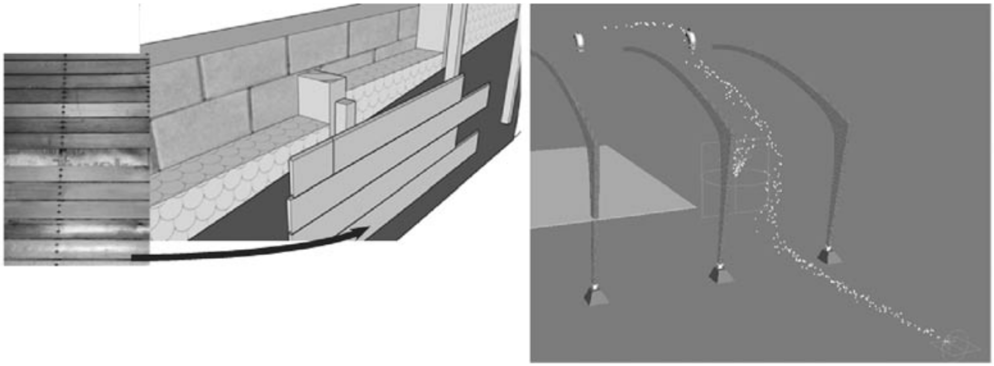


Figure 7
Model representing the cedar boarding with a waterproof membrane that was selected for the final design and simulation of air flow and heat rising through the building.

design. A summary of observations are as follows:

- *Student characteristics*: increasingly computer literate, perceive usefulness of communication techniques to enhance their job performance, access to technologies at university and via student licenses, knowledge of theoretical issues.
- *Technology characteristics*: familiar interface, non-threatening, accessible (The Virtual Environment was positioned in the center of the School), improving inter-operability, commercially available, used in practice.
- *Communication Process*: clear aims, support from staff, planned, time management capabilities, confidence, interactive, focused on exploration and decision making.
- *End Results:* continually improved over the time period of this study as the range of technologies increased and became available; effective, appropriate, credible (based on accurate source data), practical, extended traditional forms of communication.

All 55 students for 2004/2006 had some experience of professional practice, either from studying on a part-time mode or from previous years spent on professional placement. Students' qualitative evaluations on integrating new three-dimensional modelling technologies were that they could:

- Extend the traditional forms of representation.
- Be used as a tool for design as well as a tool for communication
- Improve communication for those people not familiar with interpreting 2D plans, sections and elevations. Avoid misunderstandings.
- Enable clients to not only see what his project would look like, but also to be able to interact with it.

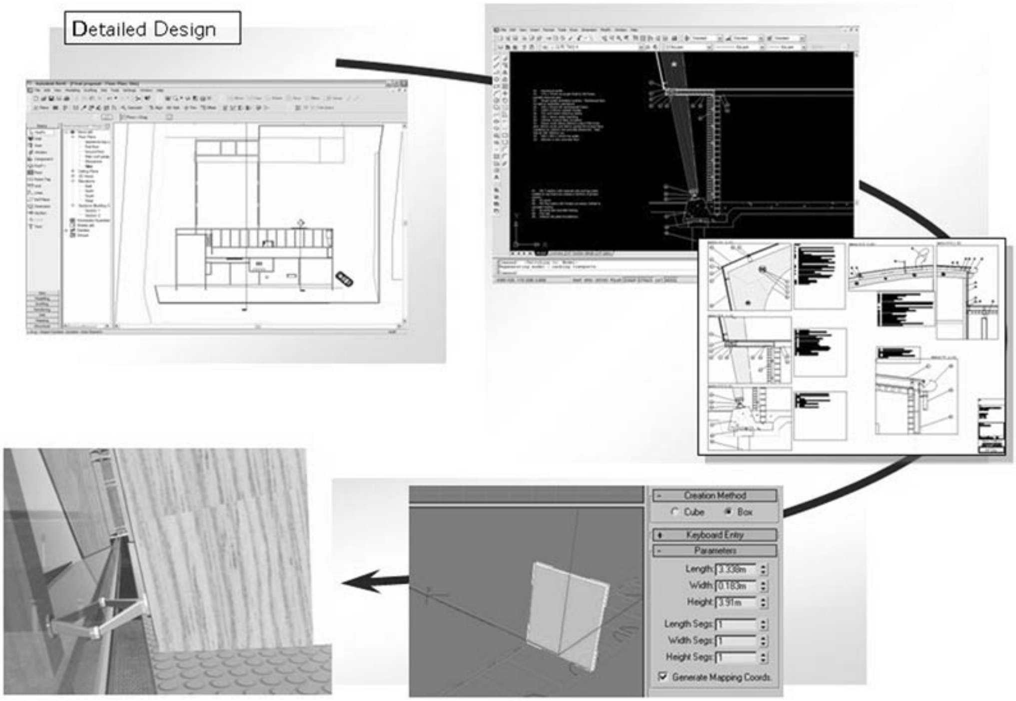


Figure 8
Detailed design using Revit, AutoCAD and 3dsMax, where materials were mapped to obtain a high level of detail.

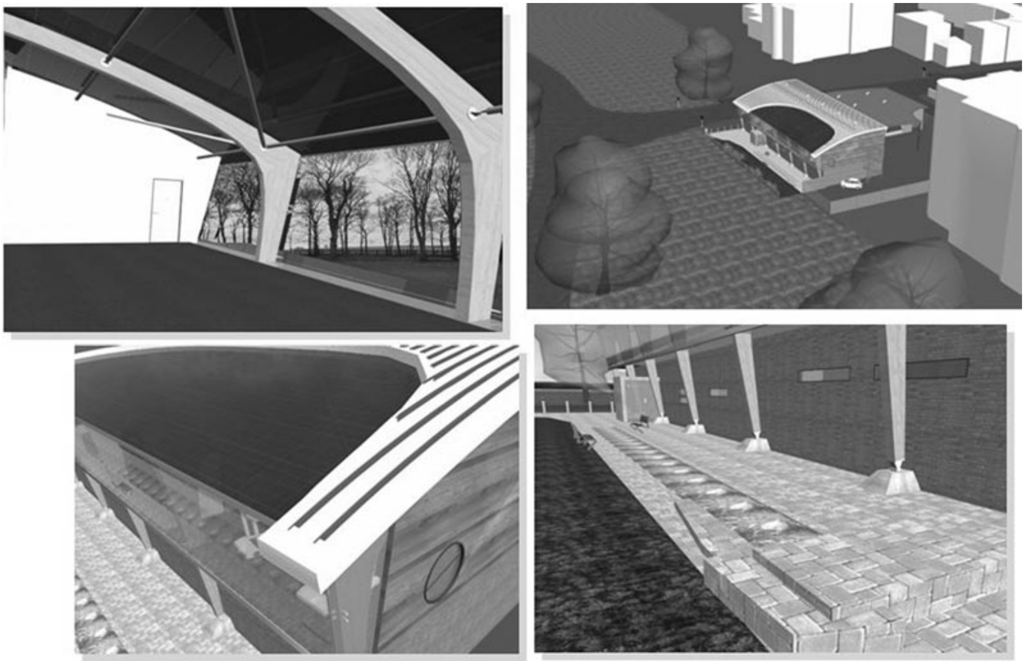


Figure 9
The completed model

- Enable clients to visualize projects in the context of their surroundings.
- Facilitate the discussion of ideas and options prior to construction. The use of interactive technology in the initial stages of project design can enable issues concerning buildability to be highlighted early in the design process. Alternative surface textures, materials and colours can be explored by easy to use screen menus.
- Enhance the image of a professional practice through using leading edge technology when submitting feasibility studies to clients.
- Attract funding and investment sources.

Conclusions

This paper has offered an analysis of the increasing range of communication techniques of use to the architectural technologist and an observation of how easier-to-use, inter-operable, three-dimensional modelling software and increasingly affordable virtual reality technologies are extending the palette of traditional techniques for communicating space. If integrated appropriately into a teaching and learning framework which links the theory of real buildings with the possibilities of the virtual, graduates will emerge with the knowledge and skills required to enable effective representation of increasingly complex buildings. The student project case study outlined how commercially available two and three-dimensional modelling and VR technologies can be appropriately applied by non-computer specialists, at various stages, to achieve a building design which considers site limitations, building legislation, feasibility and buildability. Future research will be able to report on further use of emerging technologies, issues pertaining to inter-operability and the challenges of integration into a modular curriculum which has to adapt to a profession which spans the boundaries between design and construction.

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